ALTERNATIVE DIGITIZATION APPROACH FOR STEREO PHONOGRAPH RECORDS USING OPTICAL AUDIO RECONSTRUCTION

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ABSTRACT

This paper presents the first Optical Audio Reconstruction (OAR) approach for the long-term digital preservation of stereo phonograph records. OAR uses precision metrology and digital image processing to obtain and convert groove contour data into digital audio for access and preservation. This contactless and imaging-based approach has considerable advantages over the traditional mechanical methods, such as being the only optical method with the potential to restore broken stereo records. Although past efforts on monophonic phonograph records have been successful, no attempts on 33rpm long-playing stereo records (LPs) have been reported.

By using a white-light interferometry optical profiler, we are able to extract stereo audio information encoded in the 3D profile of the phonograph record grooves.

1. INTRODUCTION

Digital archiving for phonograph recordings is already on the agenda of cultural heritage preservation work around the world. This is especially noted in the US National Recording Preservation Act of 2000. However, traditional phonograph systems are unable to restore broken records. As a result, the US Library of Congress has offered sponsorship for OAR research [1].

By utilizing precision metrology and digital image processing, OAR has been applied to wax cylinders [1] and 78rpm (revolutions per minute) records [2] [3] and has successfully extracted satisfactory audio using 2D information. Encouraged by these results, the McGill Image to Audio Conversion (MItAC) project is the first to successfully apply OAR with 3D metrology to 33rpm stereo phonograph records. Unlike mechanical systems, OAR is the only possible method for extracting audio information from damaged and broken records, which will make more historical records available for the fields such as Music Information Retrieval (MIR).

2. BASICS OF MECHANICAL PHONOGRAPH AUDIO

A mechanical sound recording system converts the acoustic energy of the sound into the groove undulations along a spiral trajectory on wax cylinders or vinyl discs. The playback system then uses a playback stylus to trace and convert the groove undulations into audio while rotating the record.

Two types of groove modulation are available for mono records: vertical and lateral. Both methods are used in combination in stereo LPs. The sum of both modulations of the stylus in the groove provides the left channel signal, while the difference provides the right channel signal.

If a disc is broken, turntable-based playback systems are not able to follow the groove modulations. OAR systems, on the other hand, have the potential of extracting its audio information by scanning the broken pieces and stitching together their groove data.

3. THE EXISTING OAR APPROACHES

Optical reproduction of sound with a laser beam has been successfully used in obtaining audio from phonograph records [4]. These laser-based systems, however, are unable to handle broken records.

Based on confocal microscopy, Fadeyev et al. devised two OAR systems for monophonic recordings: one for 78rpm records [1], and the other for an Edison Blue Amberol cylinder [2].

The system of Stotzer et al. uses a camera to rapidly photograph 78rpm records for preservation purposes. The resulting film is digitally scanned and converted in to 2D image, which is then analyzed to obtain the audio information contained in the lateral undulations [3].

None of the above methods are directed towards the reconstruction of 33rpm stereo phonograph records.

4. OAR FOR STEREO PHONOGRAPH RECORDS

4.1. White-light Interferometry Optical Profiler

Optical interferometry has been widely used in applications requiring accurate measurements of distances, displacements, and vibrations [5]. We are using a Wyko NT8000 series white-light interferometry profiler. With the ability to adjust its focus vertically, a white-light interferometer can achieve a vertical resolution of better than 1nm. At the 10X magnification (a field of view (FOV) of 0.644mm x 0.483mm), which is used in the experiment of this paper, the lateral resolution is 1μm.

According to the mechanism of the stereo phonograph recording, only the spatial positions of both top edges and the bottom of the groove are needed in order to extract the stereo audio data.

4.2. Stitching the Pieces of the Results

A disc area containing audio was divided into an array of overlapped regions of the FOV size, each of which was scanned individually. The results were then stitched together to produce a composite of the entire area. Such a stitching can be performed either in the image domain after the scan or in the audio domain after the audio extractions for all the regions. Each region is called a stitching frame (SF). In this paper, we used a simple audio-domain stitching that takes the mean amplitude in the overlapping region of both consecutive SFs.

4.3. Converting Positional Data to Audio

By tracing a selected groove in the resulting images and measuring at each spatial sample increment, the radial distances relative to the disc center and the vertical positions of the groove bottom and the top edges are obtained. The lateral and vertical stylus velocities were then derived from the positional information. Finally, the stereo signal was extracted by combining the vertical and lateral data as described in Section 2.

5. RESULTS

We used an audio system test LP [6] and measured a stereo signal with a silent left channel and a 1kHz sine wave in the right channel. The signal simplicity gives us a fairly straightforward way to validate the stereo result. The target signal shown in Figure 5.1 is measured from approximately three periods of the right-channel sine wave. The extracted lateral and vertical undulations of one of the grooves are shown in Figure 5.2. The phasing in (a) and (b) demonstrates that the resulting left and right channel signals are in accordance with the principle described in Section 2.

6. DISCUSSIONS

As an optimized setting of our profiler, with a 10X magnification, a vertical scan speed of 15μm/s, 20% inter-SF overlapping, the required time for scanning one side of an entire 33rpm stereo phonograph record area containing an audio signal is about 10 days. The required storage space for a scanned disc image is about 198GB (without compression).

7. CONCLUSION AND FUTURE WORK

OAR methods are the only way of restoring broken phonograph records. In this work, OAR is applied to the reconstruction of 33rpm stereo phonograph records for the first time in the world. In the future, more extensive experiments will be conducted on various 33rpm stereo records. Additionally, image restoration methods will be explored to improve the reconstructed audio quality.

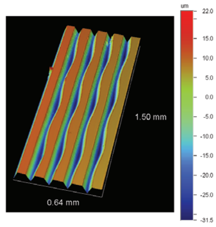
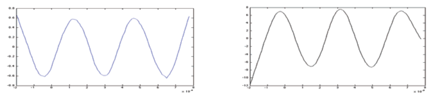


Figure 5.1. The 3D contour view of the segments of four grooves from a stereo signal with a 1kHz sine wave in the right channel and a silent left channel. The result is composed of three stitching frames, each of which is of the FOV size.



(a) (b)

Figure 5.2. The stylus velocity data extracted from the right-channel stereo groove in Figure 5.1. (a) The lateral velocity of the stylus; (b) The vertical velocity of the stylus.

8. ACKNOWLEDGEMENT

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